

TITLE OF THE INVENTION

5           BILOBAL CROSS-SECTION FIBERS AND FABRICS PREPARED  
                  THEREFROM

CROSS REFERENCE TO RELATED APPLICATION

10           This Application claims priority from and  
            incorporates by reference in its entirety U.S.  
            Provisional Application 60/212,128 filed June 16, 2000.

FIELD OF THE INVENTION

15           The present invention relates to a multifilament  
            yarn formed from filaments having bilobal cross-  
            sectional shapes in the S-shaped or Z-shaped  
            orientation. The filaments made in accordance with the  
            present invention are especially suitable in making  
20           apparel fabrics having a high moisture-wicking  
            capability, combined with a soft hand and a silk-like  
            lustrous appearance. The invention also relates to  
            hydrophilic agents useful in imparting excellent  
            wicking characteristics to fibers and articles.

25           BACKGROUND OF THE INVENTION

            There are numerous cross-section fibers used in  
            synthetic filaments for apparel, including round,  
            trilobal, ribbon, dogbone, y-shaped, and combinations  
30           thereof. Cross-sections have been developed to enhance  
            the ability of filaments to absorb or wick moisture.  
            Moisture wicking, which refers to the capillary  
            movement of water through or along the fibers, is  
            considered a desirable feature in apparel fabrics as it  
35           improves comfort to the wearer by spreading moisture  
            away from the skin so that it can evaporate more  
            readily. In addition, combinations of cross-sections,  
            denier-per-filament, and finishes applied to filaments

and fabrics have been developed to enhance the ability of filaments to absorb or wick moisture.

"Two-sided" fabrics have also been developed to help move moisture from the inside to the outside of the fabric due to the surface chemistry. Typically, the "two-sided" fabrics have fine denier per filament (dpf) filaments primarily on the outside, and courser dpf filaments primarily on the inside. Although this "two-sided" fabric is readily accomplished in weft knit fabrics through knitting construction, there is room for further improvement in wicking through optimum shape of the individual filaments. In addition, warp knit and woven fabrics are difficult and expensive to construct in a manner to maintain filament location primarily on one side or the other. Therefore, especially in wovens and warp knits, a filament that provides superior moisture wicking is needed to improve wearer comfort, especially for active wear.

There is a continuing need to provide multifilament synthetic yarns that provide soft hand and silk-like luster for apparel fabrics with enhanced moisture wicking properties.

#### SUMMARY OF THE INVENTION

In accordance with these needs, the present invention provides a multifilament yarn comprising filaments having cross-sectional bilobal S-shapes or Z-shapes, wherein the cross-section for the S or Z-shape comprises a substantially flat sided rectangular-shaped central segment having two opposite ends with a substantially flat sided arm having a curved tip portion extending from each opposite end of the central segment, wherein the width of the central segment and each arm is substantially the same, and the length of the central segment and each arm is substantially the same, wherein the angle formed between the arms and the central segment ranges from about 105° to about 165°,

and wherein the filaments have a denier per filament of between about 0.1 to about 4.0.

In another embodiment, the present invention is directed to filaments having a cross-sectional bilobal S-shape or Z-shape, wherein the cross-section for each filament comprises a substantially flat sided rectangular-shaped central segment having two opposite ends with a substantially flat sided arm having a curved tip portion extending from each opposite end of the central segment, wherein the width of the central segment and each arm is substantially the same, and the length of the central segment and each arm is substantially the same, wherein the angle formed between the arms and the central segment ranges from about 105° to about 165°, and wherein the denier per filament is between about 0.1 to about 4.0.

The present invention is further directed to fabrics formed from at least in part from filaments and yarns made in accordance with the present invention. In one embodiment, the invention is directed to a double sided fabric comprising on one-side a multifilament yarn formed at least in part from filaments having cross-sectional bilobal S-shapes or Z-shapes, wherein the cross-section for each filament comprises a substantially flat sided rectangular-shaped central segment having two opposite ends with a substantially flat sided arm having a curved tip portion extending from each opposite end of the central segment, wherein the width of the central segment and each arm is substantially the same, and the length of the central segment and each arm is substantially the same, wherein the angle formed between the arms and the central segment ranges from about 105° to about 165°, and wherein the filaments of the yarn have a denier per filament of about 0.1 to about 4.0.

The present invention also provides a hydrophilic finish useful in imparting wicking characteristics to filaments, yarns, or fabrics, such as those of the

present invention, comprising a solution of a poly(hexamethylene adipamide)-poly[poly(oxyethylene) adipamide] copolymer in water and propylene glycol.

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#### **BRIEF DESCRIPTION OF THE DRAWINGS**

Figure 1A depicts a face view of a spinneret capillary comprising three connected slots for making filaments having a Z-shaped orientation.

10        Figure 1B depicts a Z-shaped cross-sectional view of a filament spun through the capillary of Figure 1A.

Figure 2A depicts a face view of a spinneret capillary comprising three connected slots for making filaments having an S-shaped orientation.

15        Figure 2B depicts an S-shaped cross-sectional view of a filament spun through the capillary of Figure 2A.

Figures 3A, 3B, and 3C depict cross-sectional views of multifilament yarns of the present invention. Figure 3A depicts a cross-section of a multifilament  
20        yarn of the present invention having 50% S-shaped filaments and 50% Z-shaped filaments. Figure 3B depicts a cross-section having 100% Z-shaped filaments. Figure 3C depicts a cross-section having 100% S-shaped filaments.

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#### **DETAILED DESCRIPTION OF THE**

#### **PREFERRED EMBODIMENTS OF THE INVENTION**

The cross-sectional shape of the filaments of the invention is a distinctive bilobal S- or Z-shape. In  
30        referring to Figure 1B, the cross-section 100 has a substantially flat-sided, rectangular shaped central segment 110, and arms or lobes 120 attached to the central segment 110. The lobes 120 have a curved shape extending from each end of the central segment 110 such  
35        that an angle C of about 105° to 165° is formed between each of the lobes 120 and the central segment 110. The "Z-shape" cross-section is depicted in Figure 1B and the "S-shape" cross-section is depicted in Figure 2B.

Yarns formed using the filaments of the present invention can have any ratio of S-shaped or Z-shaped cross-sectional orientations. In one embodiment of the invention, the yarns are formed from a mixture of filaments having S-shaped and Z-shaped cross-sections. Figure 3A depicts a mixture of filaments having S-shaped and Z-shaped cross-sections. In particular, the S-shaped cross-section may be present in an amount of at least about 25%, e.g., at least about 50% of the filaments, for example, at least about 60%, for example, at least about 75%, and in some embodiments, about 100%, of the total filaments in the multifilament yarn. The Z-shaped cross-section may be present in an amount of at least about 25%, e.g., at least about 50% of the filaments, for example, at least about 60%, for example, at least about 75%, and in some embodiments, about 100%, of the total filaments in the multifilament yarn.

In another embodiment of the invention, the filaments of the yarns have uniform directionality. The term, "uniform directionality," as used herein refers to the orientation of the cross-sections of the filaments being substantially the same. For example, the filaments may all be in the same S-shaped orientation such as depicted in Figure 3C. Alternatively, the filaments may all be in the same Z-shaped orientation such as depicted in Figure 3B.

The filaments of the invention are composed of any thermoplastic polymer. The filaments of the present invention may be made of homopolymers, copolymers, and/or terpolymers of monomers that form melt-spinnable polymers. Melt-spinnable polymers include polyamides, such as polyhexamethylene adipamide (nylon 6,6); polycapraamide (nylon 6); polyanthamide (nylon 7); nylon 10; polydodecanolactam (nylon 12); polytetramethylenedipamide (nylon 4,6); polyhexamethylene sebacamide homopolymer (nylon 6,10); a polyamide of n-dodecanedioic acid and

hexamethylenediamine homopolymer (nylon 6,12); and a polyamide of dodecamethylenediamine and n-dodecanedioic acid (nylon 12,12); polyesters, such as polyethylene terephthalate ("2-GT"), polytrimethylene terephthalate ("3-GT"), polybutylene terephthalate ("4-GT"), polypropylene terephthalate, and polyethylene naphthalate; polyolefins, such as polypropylene, polyethylene, and polyurethane; and combinations thereof. Methods of making the homopolymers, copolymers and terpolymers used in the present invention are known in the art and may include the use of catalysts, co-catalysts, and chain-branchers to form the copolymers and terpolymers, as known in the art. Preferably, the fiber-forming polymer is at least one polyamide, since polyamides are generally softer due to the lower modulus, and they are more hydrophilic due to the surface chemistry of these polymers. More preferably, the polymer is nylon 6, nylon 6,6, or a combination thereof. Most preferably, the polyamide is nylon 6,6.

The polymers and resultant filaments, yarns, and articles used in the present invention can comprise conventional additives, which are added during the polymerization process or to the formed polymer or article, and may contribute towards improving the polymer or fiber properties. Examples of these additives include antistatics, antioxidants, antimicrobials, flameproofing agents, dyestuffs, light stabilizers, polymerization catalysts and auxiliaries, adhesion promoters, delustrants, such as titanium dioxide, matting agents, organic phosphates, and combinations thereof.

The polymers and resultant filaments, yarns, and articles used in the present invention can be treated on their surface with permanent or semi-permanent hydrophilic treatments or finishes. These treatments improve the moisture wicking property of the articles.

Suitable wicking treatments useful in the present invention include hydrophilic polymeric compositions, such as polyamides made with hydrophilic segments, such as poly(hexamethylene adipamide)-poly[poly(oxyethylene) adipamide] copolymers [CAS No. 92717-79-8], such as described in U.S. Patent No. 4,468,505 incorporated herein by reference in its entirety; hydrophilizing silicone microemulsions, such as "Sandotor HV Liquid", which is commercially available from Clariant; hydrophilic copolyesters, such as a copolyester containing both polyoxyethylene diester and alkylene diester segments; and certain nonionic surfactants, such as those described in Canadian Patent 1,234,656.

These wicking treatments vary in their ability to improve water wicking performance and vary in their durability or resistance to removal by washing. This variability in performance depends on several factors including the composition of the treated fiber, the amount of wicking treatment applied to the fiber, and the resistance of the treatment to washing.

The poly(hexamethylene adipamide)-poly[poly(oxyethylene) adipamide] copolymers have been found to be particularly useful to treat articles of the present invention. The polymers are composed of polyoxyethylene adipamide segments and poly(hexamethylene adipamide) segments. The poly(oxyethylene) adipamide segments are formed from the reaction of a poly(oxyethylene) diamine [CAS No. 65605-36-9] with adipic acid. The poly(oxyethylene) diamine can include minor amounts, for example, less than 25 mol % oxypropylene groups with the oxyethylene groups.

The polyoxyethylene adipamide segments have high affinity for water and impart hydrophilic character to the copolymer and thus to the treated fiber, while the poly(hexamethylene adipamide) segments have low water solubility and thus impart permanence to the treatment on the fiber. These adipamide copolymers are

especially useful when the polymer used in the substrate to be treated is nylon 6, nylon 6,6, or combinations thereof, and are most preferred for use  
5 when the polyamide substrate is nylon 6,6.

The length of each of the polyoxyethylene adipamide and poly(hexamethylene adipamide) segments may be varied. Increasing the length of the polyoxyethylene adipamide segments increases the water  
10 wicking property of the treatment while simultaneously increasing its water solubility and thus decreasing its durability to washing. Increasing the length of the poly(hexamethylene adipamide) segments decreases its water solubility and thus increases its durability of  
15 the treatment to washing.

The suitable length of the polyoxyethylene adipamide segment is also determined to an extent by commercial availability of the poly(oxyethylene) diamine. Poly(oxyethylene) diamines with molecular  
20 weights of 600, 900, and 2000 are available from Huntsman Corporation, and hence are especially useful. They are known as XTJ-500, XTJ-501, and XTJ-502.

The relative amount of each of these segments to each other in the treatment composition may also be  
25 varied in any desired ratio. Increasing the proportion of polyoxyethylene adipamide segments increases the water wicking property of the treatment while simultaneously increasing its water solubility and thus decreasing its durability to washing. Conversely,  
30 increasing the proportion of the poly(hexamethylene adipamide) segments decreases its water solubility and thus increases its durability to washing. Balancing the relative amounts and lengths of the polyoxyethylene adipamide and poly(hexamethylene adipamide) segments in  
35 the copolymer can be done to maximize the water wicking performance while maintaining suitable durability to repeated washing. A preferred copolymer for the present invention employs poly(oxyethylene) diamines of molecular weight between about 900 and about 2000 with



weight percentages of nylon 6-6 ranging from about 18-22%. The polymers can be made as described in U.S. Patent No. 4,468,505.

5        These copolymers can be dissolved in any suitable solution when used in the present invention. A preferred system has been found to be a solution of 1,2-propanediol and water. This combination provides a solution that may be either applied to fabrics by  
10    itself or in combination with other processing agents as described below. The amount of poly(hexamethylene adipamide)-poly[poly(oxyethylene) adipamide] copolymer in the solution may range from about 0.1% to about 40% by weight. The most preferred range is from about 8 %  
15    to about 15%. At higher percentages of copolymer the solution has a tendency to gel. Lower percentages are acceptable, but are less economical. For application to fabric, the solution may be further diluted with water to facilitate the application of only the desired  
20    amount of finish without overapplication.

1,2-propanediol is used to facilitate dissolution of the copolymers in water. A preferred amount of 1,2-propanediol is approximately equal in weight to the hydrophilic polyamide copolymer. More 1,2-propanediol  
25    may be used (e.g. 1.5 times the weight of copolymer), but may lengthen the drying time required in the application process. Less 1,2-propanediol may be used (e.g. 0.5 times the weight of copolymer), but reduces the solubility of the hydrophilic polyamide copolymer.  
30    The use of 1,2-propanediol is preferred over ethanol as taught in U.S. Patent No. 4,468,505 because it is not flammable, it is less toxic, less carcinogenic, less of it may be used, and it has a higher boiling point and so is less fugitive.

35    Hydrophilic copolyesters are also useful hydrophilic agents in the present invention. Hydrophilic copolyesters include copolyesters containing both polyoxyethylene diester and alkylene diester segments. They may be simple copolyesters,

i.e., they may contain only polyoxyethylene diester and polyalkylene diester segments, the copolyester being derived from a single polyethylene oxide, diester and glycol. Polyethylene oxides of various molecular weights, dimethyl terephthalate, and ethylene glycol are the most common raw materials for these copolymers, mainly because of cost and availability. Numerous variations on the comonomers used to prepare these simple hydrophilic copolyesters are possible. These copolymers are disclosed in U.S. Patent 3,416,952, incorporated herein by reference in its entirety. Examples of these copolymers include "ZELCON" 5126 [CAS No. 9074-67-3] which is commercially available from Stepan Company, and "MILEASE" T [CAS No. 9016-88-0] which is commercially available from Imperial Chemical Industries, Limited, London, England Both "ZELCON" 5126 and "MILEASE" T are sold in an aqueous dispersion form containing up to 85% water.

These permanent or semi-permanent hydrophilic treatments compositions previously described may be applied to the fabric or fiber by any suitable means such as wiping, painting, dipping, foaming, feeding at the nip of a roller, spraying, or other means. The composition is typically applied at a minimum level of at least 0.1 % weight of solids on fiber, preferably at least 0.5 % weight of solids on fiber, to achieve water wicking and durability. Application at higher levels will improve hydrophilic character. After drying or removal of the solvent, a durable hydrophilic coating remains on the fabric or fiber surface. This coating causes water placed on the surface to rapidly wet the fabric and to move along the fiber length and through the fabric layer.

Other additives that may be applied on the fibers, for example, during spinning and/or drawing processes include antistatics, slickening agents, adhesion promoters, antioxidants, antimicrobials, flameproofing agents, lubricants, and combinations thereof.

Moreover, such additional additives may be added during various steps of the process as is known in the art.

Filaments of the invention can also be formed from  
5 two polymers, such as two nylons, or two polyesters, into so-called "bicomponent" filaments. Also, the filaments of the present invention having the bilobal cross-section, including those formed as bicomponents, can be mixed with filaments of other cross-sections  
10 and/or polymers to form yarns.

The filaments of the present invention are formed by any suitable spinning method, which may vary based upon the type of polymer used, as is known in the art. Generally, the melt-spinnable polymer is melted and the  
15 molten polymer is extruded through a spinneret capillary orifice having a design corresponding to the desired bilobal cross-section of the present invention. The extruded fibers are then quenched or solidified with a suitable medium, such as air, to remove the heat  
20 from the fibers leaving the capillary orifice. After quenching, the filaments are converged, interlaced, and wound as a multifilament bundle.

The spinneret capillary used to produce the filaments of the present invention can be any suitable  
25 capillary capable of producing the bilobal cross-section described above. One suitable spinneret is described, for example, in U.S. Patent No. 5,447,771, herein incorporated by reference. In particular and as described in instant Figures 1A and 2A, spinnerets  
30 include a plate having upper and lower surfaces connected by a segmented capillary. The segmented capillary includes a central portion and two radial arms with each being rectangular in shape. As shown in Figures 1A, 1B, and 2B, the angle (C1 or C2) is the  
35 angle between one arm and the central portion. Angle C1 typically is between about 105° to about 165°. Angle C2 typically is between about 105° to about 165°. The angles C1 and C2 of the cross-section may be the same or different. Preferably, the angles are

substantially the same. Preferably, for the S-shaped cross-section, the angle C1 and C2 for each arm (as shown in Figure 2B) is between about 105° to about 165°, most preferably between about 120° to about 135°. Preferably, for the Z-shaped cross-section, the angle C1 and C2 (as shown in Figure 1B) is between about 105° to about 165°, most preferably between about 120° to about 135°.

Moreover, referring to Figure 2A, the slots may have any length (A1 and A2), for example, about 0.005 to about 0.050 inches, preferably between about 0.010 to about 0.020 inches, and any width (B1 and B2), such as between about 0.001 to about 0.015 inches, preferably about 0.003 to about 0.005 inches. The central portion 110 can have any length (D), for example, between about 0.005 to about 0.025, preferably between about 0.012 to about 0.020, and any width (E), for example, between about 0.001 to about 0.015 inches, preferably about 0.003 to about 0.005 inches. Fig. 1A can have analogous dimensions.

The dimensions for each slot in a preferred embodiment are further defined by the following ratio:

$$1.5 < A1/B1 < 10,$$

wherein A1 is the length of a slot and B1 is the width of the slot. The formula for the second arm would be  $1.5 < A2/B2 < 10$ , wherein A2 is the length the other slot and B2 is the width of that slot. Generally, the spinneret capillary should have the foregoing dimensions in order that filaments of this invention may be prepared. However, it is understood that specific dimensions and ratios, within the above ranges, may vary depending upon such factors as polymer type, viscosity, and quench medium. It is also recognized that the shape of the slots may be modified, e.g., as shown in Figure 1A, where the tip portion of the radial slots is slightly curved. Preferably, each of the radial slots is substantially the same size and shape.

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The spinneret capillaries through which the molten polymer is extruded are cut to produce the desired cross-section of the present invention. Figures 1A and 2A depict face views of the capillaries to form the filaments. The capillaries or spinneret bore holes may be cut by any suitable method, such as by laser cutting, as described in U.S. Patent No. 5,168,143, herein incorporated by reference, drilling, Electric Discharge Machining (EDM), and punching, as is known in the art. Preferably, the capillary orifice is cut using a laser beam. The orifices of the spinneret capillary can have any suitable dimensions and may be cut to be continuous slots or non-continuous slots. A non-continuous capillary may be obtained by boring small holes in a pattern that would allow the polymer to coalesce and form the bilobal cross-section of the present invention.

The filaments can be formed into any type of yarn, for example, fully drawn yarns or partially oriented yarn, as used, for example, in texturing feed yarns. Accordingly, in one embodiment, the filaments are spun as a fully drawn yarn, for example, a yarn having an orientation of about 35 to about 50% elongation to break, which may be immediately used in manufacturing articles. Optionally, however, the filaments of the present invention may be textured, also known as "bulked" or "crimped," according to known methods. In this embodiment of the invention, the filaments may be drawn as a partially oriented yarn, for example, a yarn having an orientation of about 55 to about 75% elongation to break, and then textured by techniques, such as by draw false-twist texturing, air-jet texturing, gear-crimping, and the like.

The filaments of the invention can be processed into a multifilament fiber or yarn having any desired denier, filament count, and dpf. The yarn formed from the filaments of the present invention typically has a total denier between about 10 and about 300 denier,

preferably, between about 15 and about 250 denier, and most preferably, between about 20 and about 150 denier. The filaments of the present invention also typically  
5 have a denier per filament between about 0.1 to about 4 dpf, preferably, between about 0.8 to about 3.5, and most preferably, between about 0.9 to about 3.0. In one embodiment, the dpf is less than about 2.9, or less than about 2.5. The bilobal filaments can be mixed  
10 with other filaments, for example, having a dpf above or below about 4.

The yarns of the present invention may further be formed from a plurality of different filaments having different dpf ranges. In such case, the yarns should  
15 be formed from at least one filament having the multilobal cross-section of the present invention. Preferably, each filament of a yarn containing a plurality of different filaments has the same or different dpf, and each dpf is between about 0.1 to  
20 about 4 dpf, preferably, between about 0.8 to about 3.5, and most preferably, between about 0.9 to about 3.0.

The filaments of the present invention may be used to make fabrics. Any known suitable method of making  
25 fabrics may be used. For example, warp knitting, circular knitting, hosiery knitting, and laying a staple product into a non-woven fabric are suitable for making fabrics. In one embodiment, two-sided fabrics are made using the filaments of the present invention  
30 on primarily one side of the fabric. Any other type of yarn may be used to make up the other side of the fabric, but preferably it has a different wicking ability. Suitable yarns for the other side of the two-sided fabric may be made up of polyamides, polyesters,  
35 polyolefins, natural fibers, such as cotton, wool, silk, rayon, and combinations thereof. The two-sided fabrics may be made by methods known in the art. For example, the fabrics may be knitted using the multifilament yarn having bilobal cross-sections of the

present invention on one side and another yarn on the other side. Suitable methods of making the two-sided fabrics include warp knitting and plating the yarns.

- 5 The two-sided fabrics have the benefit of allowing moisture to be drawn away from the body. Generally, the higher dpf fabric is used on the inside of a garment, and the lower dpf fabric is used on the outside of the garment. However, the bilobal cross-section multifilament yarns of the present invention may be used on either side of the two-sided fabric. For example, the bilobal cross-section multifilament yarns of the present invention may be used on the outside of the fabric and treated with a finishing agent, such as a hydrophilic agent as described above.
- 10 In another embodiment, a different yarn, such as cotton, may be used to form the outside of the fabric with the bilobal multifilament yarns on the inside.

- In another preferred embodiment, the fabric is formed from at least about 50%, preferably at least about 80%, of the filaments of the present invention based on the total number of filaments. In yet another preferred embodiment, the fabric formed from the filaments of the present invention is combined with a permanent or semi-permanent hydrophilic wetting agent as described above. The fabrics are useful to make any type of apparel, including swimwear, active wear, and ready-to-wear garments.
- 15 20 25

- Any desired additional agent may be applied directly to the fabrics. Examples of these additives include antistatics, antioxidants, antimicrobials, flameproofing agents, dyestuffs, light stabilizers, polymerization catalysts and auxiliaries, adhesion promoters, delustrants, such as titanium dioxide, matting agents, organic phosphates, permanent or semi-permanent hydrophilic wetting agent, and combinations thereof. Preferably, a suitable wetting agent is added to fabrics made using the multifilament yarns of the present invention. Suitable wetting agents for
- 30 35

application directly to the fabric include hydrophilic agents, as described above.

The fabrics made using the filaments and yarns of the present invention have been found to exhibit excellent moisture wicking properties, soft hand, and silk-like luster. Multifilament yarns of high dpf filaments have been developed for use in carpets that have a bilobal cross-sections in opposite directionality. For example, Mill et al., U.S. Patent No. 5,447,771, describes multifilament yarns, wherein in the cross-sections, "S" and "Z", are present in ratios of 40:60 up to 60:40. The present inventors have surprisingly found that the S and Z cross-sections filaments can be used to form apparel with excellent wicking characteristics, especially at dpf of less than about 4.

The moisture wicking of the yarns of the invention is determined by known methods, such as by a vertical wicking test or a horizontal wicking test. The vertical wicking test may be conducted by knitting the yarns into tubes, and then either scouring or treating the tubes with any desired agent and allowing the treated tubes to air dry. The tubes are then cut into 1 inch wide strips about 8 inches long and suspended vertically above water with 3 inches in the water and 5 inches above the water. Observations of the height of the water being wicked up the strips are conducted visually at predetermined times, such as at 1 minute, 5 minutes, 10 minutes, and 30 minutes.

The mixed S- and Z-shaped cross-sections having a denier per filament of between about 0.1 to about 4.0 has been found to exhibit increased moisture wicking. Superior results have also been found for multifilament yarns having directionally uniform S-shaped or Z-shaped cross-sections as described herein.

The yarn of the present invention have a tenacity suitable for use in apparel. Tenacity is measured on an Instron equipped with two grips which hold the yarns



at the gauge lengths of 10 inches. The yarn is then pulled by the strain rate of 10 inch/minute, the data are recorded by a load cell, and stress-strain curves are obtained. Tenacity is the breaking strength (in grams) divided by the yarn's denier. Both partially oriented yarns and fully drawn yarns of the present invention can have a tenacity of between about 2 to about 8, preferably between about 3 to about 6 grams per denier.

The elongation-to-break of the yarn can be measured using any known apparatus. For example, one method involves pulling to break on an Instron Tester TTB (Instron Engineering Corporation) with a Twister Head made by the Alfred Suter Company and using 1-inch x 1-inch flat-faced jaw clamps (Instron Engineering Corporation). Samples typically about 10-inches in length are subjected to two turns of twist per inch at a 60% per minute rate of extension at 65% Relative Humidity and 70°F. The elongation to break for both fully drawn yarns and partially oriented yarns of the present invention was between about 30% to about 80%, preferably between about 40% to about 60%.

The boil off shrinkages of the yarn may be measured using any known method. For example, it may be measured by suspending a weight from a length of yarn to produce a 0.1 gram/denier load on the yarn and measuring its length ( $L_0$ ). The weight is then removed and the yarn is immersed in boiling water for 30 minutes. The yarn is then removed, loaded again with the same weight, and its new length recorded ( $L_f$ ). The percent shrinkage (S) is calculated by using the formula:

$$\text{Shrinkage (\%)} = 100 (L_0 - L_f) / L_0$$

A low shrinkage is highly desirable for most textile purposes. The yarns of the present invention have a shrinkage less than about 10%, preferably less than about 7%, most preferably less than about 6%.

The invention will now be illustrated by the following non-limiting examples.

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EXAMPLES

Preparation of poly(hexamethylene adipamide)-  
poly[poly(oxyethylene) adipamide] copolymer used in the  
finish of example 1

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Polyoxyalkyleneamine XTJ-501 (Huntsman, CAS 65605-36-9, mol. wt 900) 506 g, adipic acid 82.1 g, and 277.6 g of nylon salt solution (53.2% solution in water of a 1:1 molar ratio mixture of hexamethylene diamine and adipic acid heated until homogeneous) were combined in a 2 l resin kettle equipped with a mechanical stirrer, thermocouple, agitator blade, distillation head, and N<sub>2</sub> line. Stirring was started, then all air was removed by evacuating and breaking with nitrogen 3 times. The mixture is a thin white slurry. The mixture was heated rapidly to a pot temperature of 120° C to distill of water. A nitrogen sweep was used to facilitate water removal throughout the reaction period. Steam heating or heat tape on the top of the kettle can be used to reduce water refluxing. Once the water distillation slows (approximately 130 ml collected) the mixture was, heated to a pot temperature of 200° C, and held for 4 hours. Water is continued to be distilled and the mixture heated to 260° C over one hour and held at 260° C for 30 minutes, then cooled to room temperature. The solid polymer was removed from the flask and chopped or ground into desired pieces.

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Preparation of poly(hexamethylene adipamide)-  
poly[poly(oxyethylene) adipamide copolymer solution

1,2-propylene glycol 100g and water 800 g were combined and heated to 90 - 95° C in a blender. 100 g of the poly(hexamethylene adipamide)-

poly[poly(oxyethylene) adipamide copolymer prepared above was added and stirred rapidly for 30 minutes to dissolve it. The solution was filtered through a cloth  
5 filter to remove undissolved particulates, then a small amount of glutaraldehyde (670 ppm) (Ucarcide 225) was added as a preservative.

### Example 1

10 A 40 denier-14 filaments bilobal cross-section yarn was spun with 50% of the filaments being "S"-shaped, and 50% of the filaments being "Z"-shaped. The filaments were spun at a temperature of 290°C. The yarn was spun with nylon 6,6, having a relative  
15 viscosity (RV) of between 45-47. A normal nylon pack formulation was used using spinnerets in a configuration of 3 ends/pack having the bilobal cross-section. The nylon 6,6 was spun at a windup speed of 3000-3200 yards per minute and drawn at a draw ratio of  
20 2.5-2.7 X. The tenacity of the filaments was 3.6 grams per denier, and the yarn had an elongation to break of 42%. The yarn had a cross-section similar to that set forth in Figure 3A. Normal spin/secondary spin finishes were used.

25 The yarn was knitted into Lawson tubing on a single end knitter. After knitting into tubing, each product in the examples above was tested via a vertical wicking test. The product was prepared two ways: (1) scoured thoroughly to remove all finishes, and (2)  
30 subsequently treated with a hydrophilic wicking agent, then air dried. The particular hydrophilic finish used in this testing was a dispersion of the copolymer as prepared above. The product was then cut into 1 inch wide strips about 8 inches long and then suspended  
35 vertically above the water with 3 inches in the water and 5 inches above the water. The experimenter then visually observed the height the water wicked up the strip, up to 5 inches. Observations were made at 1 minute, 5 minutes, 10 minutes, and 30 minutes. The

test was stopped when 5 inches were achieved. Controls of round, trilobal and dogbone cross-sections of nylon 6,6 were used for comparison. Interestingly, the different cross-sections did not wick very well when scoured, but the results changed dramatically when treated with the hydrophilic finish. The bilobal cross section benefited the most, by far, from the addition of the hydrophilic finish. The results are summarized in the Table I.

#### Example 2

A 40 denier - 14 filaments bilobal cross-section yarn having 100 % S-shaped filament cross-sections and spun using nylon 6,6, was made in a manner analogous to Example 1. The tenacity of the filaments was 4.3 grams per denier, and the yarn had an elongation to break of 41%. Furthermore, the yarn had a boil off shrinkage of 5.3% and were interlaced at 11 nodes per meter. The yarn had a cross-section similar to that set forth in Figure 3C. The moisture wicking capabilities of the yarn were then tested in a vertical wicking test as reported in Table 1.

#### Example 3

A 40 denier - 14 filaments bilobal cross-section yarn having 100 % Z-shaped filament cross-sections and spun using nylon 6,6 was made in a manner analogous to Example 1. The moisture wicking capabilities of the yarn were then tested in a vertical wicking test as reported in Table 1. The yarn had a cross-section similar to that set forth in Figure 3B. The yarn had similar denier, elongation, and boil off shrinkage as the yarn of Example 1.

#### Example 4

A 44 denier - 14 filaments bilobal partially oriented yarn was spun having 50% S-shaped filament cross-sections and 50% Z-shaped filament cross-section

using nylon 6,6 in a manner analogous to Example 1 except that the Draw Ratio was reduced to 1.9 X. The yarn had a cross-section similar to that set forth in Figure 3A. The tenacity of the filaments was 3.1 grams per denier, and the yarn had an elongation to break of 59%.

#### Example 5

10 A 80 denier - 28 filaments bilobal cross-section yarn having 50% S-shaped and 50% Z-shaped filament cross-sections and spun using nylon 6,6, was made in a manner analogous to Example 1. The tenacity of the filaments was 4.2 grams per denier, and the yarn had an  
15 elongation to break of 42%. The boil off shrinkage of the yarn was 6.0% and the yarn was interlaced at a rate of 15 nodes per meter. The moisture wicking capabilities of the yarn were then tested in a vertical wicking test as reported in Table 1. However, since  
20 the standard test reached the maximum of 5 inches in 30 minutes, an additional test was run on the treated 80-28 yarn with a longer strip, and it was found that the wicking continued past the 5 inches, up to 6.2 inches in 30 minutes for the 80-28 bilobal item.

25

#### Comparative Examples A-F

Comparative yarns were formed in a manner analogous to Example 1 having the denier-filaments and cross-sections set forth in Table 1. Each of the yarns  
30 were made from nylon 6,6. The moisture wicking capabilities of the yarn were then tested in a vertical wicking test as reported in Table 1.

TABLE I

Example	Denier-Filaments	Cross-section	Treatment	Height (inches) Wicking			
				1 min	5 min	10 min	30 min
1	40-14	Bilobal (50% S, 50% Z)	Scoured	0.30	0.35	0.45	0.65
1	40-14	Bilobal (50% S, 50% Z)	Treated	1.75	2.85	3.75	5.00
2	40-14	Bilobal (100% S)	Scoured	0.35	0.40	0.50	0.75
2	40-14	Bilobal (100% S)	Treated	1.70	2.95	3.85	5.00
3	40-14	Bilobal (100% Z)	Scoured	0.30	0.35	0.55	0.70
3	40-14	Bilobal (100% Z)	Treated	1.65	2.80	3.80	5.00
5	80-28	Bilobal (50% S/ 50% Z)	Scoured	0.30	0.35	0.45	0.65
5	80-28	Bilobal (50% S/ 50% Z)	Treated	1.70	2.95	3.85	5.00
Comp A	70-51	Round	Scoured	0.10	0.10	0.25	0.55
Comp A	70-51	Round	Treated	0.75	1.55	2.00	2.75
Comp B	70-24	Trilobal	Scoured	0.40	0.75	0.95	1.40
Comp B	70-24	Trilobal	Treated	0.95	2.05	2.70	3.70
Comp C	70-66	Round	Scoured	0.20	0.50	0.75	1.55
Comp C	70-66	Round	Treated	1.10	1.90	2.35	2.95
Comp D	86-26	Dogbone	Scoured	0.40	0.40	0.40	1.10
Comp D	86-26	Dogbone	Treated	1.15	2.05	2.80	3.85
Comp E	70-34	Round	Scoured	0.40	0.50	0.55	1.30
Comp E	70-34	Round	Treated	0.50	1.00	1.55	2.65
Comp F	70-34	Trilobal	Scoured	0.40	0.40	0.60	0.95
Comp F	70-34	Trilobal	Treated	0.95	1.75	2.45	3.65

5 As set forth in Table 1, the treated bilobal cross-section of the present invention far exceeded the other cross-sections in its wicking ability. For example, the treated bilobal yarns of the present invention each completely wicked the full length of the

10 yarn over 30 minutes. This was particularly unexpected since the trilobal and dog bone cross-sections had better wicking performance than the bilobal when tested as scoured fabrics, but not when treated with

15 hydrophilic finish. Accordingly, the synergy between the bilobal cross-section and the hydrophilic finish was unexpected. It is believed that this synergy may relate to the way the bilobal fibers lay together to form tiny capillaries between the fibers, which enhance the wicking once the fiber surface is wet due to the

hydrophilic finish, and which is not obtained for the trilobal and dog bone cross-sections.

5

Example 6

The yarn of Example 1 and yarns having varying cross-sections, such as dog bone and round, were spun using nylon 6,6. Each of these yarns were weft-knitted into a predominantly "2 sided structure" with 70 denier  
10 34 filament nylon 6,6 as the second yarn, wherein there was a 50% weight percent of each yarn in the fabric. The 2-sided nature of the fabrics was achieved by controlling knitted stitch length and feed tension to the knitting machine. These fabrics were then dyed and  
15 finished via normal techniques for nylon. Sandator HV Liquid from Clariant was applied as a hydrophilizing agent.

The wicking testing was involved a method of testing both the wicking rates and fabric absorption in  
20 a single test. In particular, the test involved using an apparatus including a porous plate 55 mm in diameter, fixed in a wooden stand to ensure stability and connected to a length of non-compressive flexible tubing. The flexible tubing was placed in a one liter  
25 liquid reservoir with the reservoir placed on an electronic balance to measure weight of liquid remaining in the reservoir. As water wicked into the fabric from the reservoir, a computer connected to the balance recorded weight loss to determine water  
30 absorption. The fabric was cut into samples 120mm by 130 mm and placed on top of the porous plate with a cylindrical mass on top to promote contact with the wet porous plate. The total bulk absorption of the fabric was measured and the rate of wicking was calculated  
35 from the data. The results of this test are set forth in Table 2.

TABLE 2

CROSS-SECTION OF YARNS	WICKING RESULTS	
	Surface Water Accumulation Capacity (g of H <sub>2</sub> O/square meter)	Surface Water Transport Rate (g of H <sub>2</sub> O/square meter/ sec.)
Bilobal Cross-section (Example 5)	565	6.14
Dogbone	417	4.81
Round	377	4.09

5

As set forth in Table 2, the bilobal cross-section of the present invention far exceeded the other cross-sections in its ability to accumulate surface water and absorb water.

10 Those skilled in the art, having the benefit of the teachings of the present invention as hereinabove set forth, can effect numerous modifications thereto. These modifications are to be construed as being encompassed within the scope of the present invention

15 as set forth in the appended claims.